HOT SPRINGS DEPOSITS OF THE COSO MOUNTAINS *

By H. J. Fraser, H. D. B. Wilson, and N. W. Hendry

OUTLINE OF REPORT

INTRODUCTION

The Coso Hot Springs region is located in the central part of the Coso Mountains, California. Knowledge of the hot springs predates early California mining days; use of the springs for medical purposes continues to the present day. The existence of mercury minerals in the solfataric altered zones was discovered in the early 1920's and led to considerable exploration and some mining in two major areas southwest of the village of Coso Hot Springs. The settlement, located in T. 22 S., R. 39 E., M. D., Inyo County, about 11 miles northeast of Coso Junction, a station on the Southern Pacific Railroad, can be reached by either of two graded gravel roads which run easterly from Highway 395. Coso Junction lies about 2 miles north of Little Lake.

Early reconnaissance work was done in the Coso Mountains by Fairbanks,[1] Gilbert,[2] and Spurr.[3] The cinnabar deposits have been described by Warner [4] and reviewed more recently by Ransome and Kellogg.[5]

The district surrounding the hot springs is one of relatively recent volcanic activity. Many fumaroles are still active. Active leaching and alteration of the wall rocks is in progress and native sulphur, iron, and aluminum sulphates, and possibly cinnabar are still being deposited. The area presents an interesting example of intense solfataric alteration in siliceous rocks.

* Contribution No. 336, Balch Graduate School of the Geological Sciences, California Institute of Technology, Pasadena, California. Manuscript submitted for publication June 1, 1942.

[1] Fairbanks, H. W., The mineral deposits of eastern California: Am. Geologist, vol. 17, pp. 144-158, 1896.

Fairbanks, H. W., Geology of California: Am. Geologist, vol. 17, pp. 63-76, 1896.

[2] Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona: U S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol 3, p. 124, 1875.

[3] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U S. Geol. Survey Bull. 208, 229 pp., 1903.

[4] Warner, Thor, Mercury deposit in Coso Range, Inyo County, California: California Dept. Nat. Resources, Div. Mines, State Mineralogist's Rept. 26, pp. 59-63, 1930.

[5] Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Dept. Nat. Resources, Div. Mines, California Jour. Mines and Geology, State Mineralogist's Rept. 35, pp. 378-380, 1939.

Elevations in the Coso Mountains vary from an average of 3,700 feet in Owen's Valley to a maximum of 8,156 feet at the summit of Coso Peak. Elevations in the area mapped and discussed herein vary from a minimum of 3,635 feet at Coso Hot Springs to a maximum of about 4,700 feet.

GENERAL GEOLOGY

The central part of Coso Mountains is composed of very coarse-grained granitic rock. Areas of diorite, hornblende gabbro, and other basic rocks occur in the granite, some as gneissic or schistose zenoliths, others as elongated dike-like masses which apparently intruded the granite. Lying upon the deeply weathered and eroded surface of the granite basement are a number of alluvial fans, best seen along the western flank of the range but also present along the northern and northeastern borders. The southern part is covered in many places by extensive but relatively thin beds of well-stratified tuff and volcanic breccia. The tuff, breccia, and alluvium all dip away from the crest of the range at low angles ranging between 6 and 10 degrees. Above the tuffs and conformable with them is a basaltic lava 50 to 100 feet thick. Associated with this lava in places are partially preserved basaltic cinder cones. Subsequently there were extensive flows of rhyolitic material; well-formed rhyolitic cinder cones may be seen along a north-south line about 3 miles west of Coso Hot Springs. In places these late rhyolite flows are covered with a shallow mantle of ash and volcanic tuff, some of which is unconsolidated, but in other places it is cemented by fine-grained silica.

Coso hot springs are situated in Coso basin, which covers approximately one square mile and is bounded by faults on the east and west sides. The entire region has undergone repeated faulting, the later stages of which are clearly shown in the basalt flows east of Coso basin. The basin, which is filled with tuff and alluvium, is bounded on the west and north by granite, and on the northeast, east, and southeast by basalt.

According to Schultz,[6] the later geological history of Coso Mountains may be summarized as follows:

1. Faulting or possibly warping which elevated the granitic core and made possible the accumulation of alluvial fan material to a depth of at least 300 feet. This material is now preserved mainly along the western and northern margins of the range.
2. Explosive volcanic activity with subsequent deposition of substantial thickness of tuffaceous material largely deposited in standing water.
3. Extensive outflows of basalt which covered the sediments.
4. Normal faulting followed by active erosion.
5. A renewal of volcanic activity and the extrusion first of basaltic flows, particularly around Little Lake, and later rhyolitic material, ash and tuff.

On the basis of some vertebrate fossils found in the sediments underlying the older tuff beds, Schultz [7] dated these sediments as transitional between lower and upper Pliocene. Consequently all of the volcanic activity is later than upper Pliocene and some undoubtedly belongs in the late Pleistocene or Recent.

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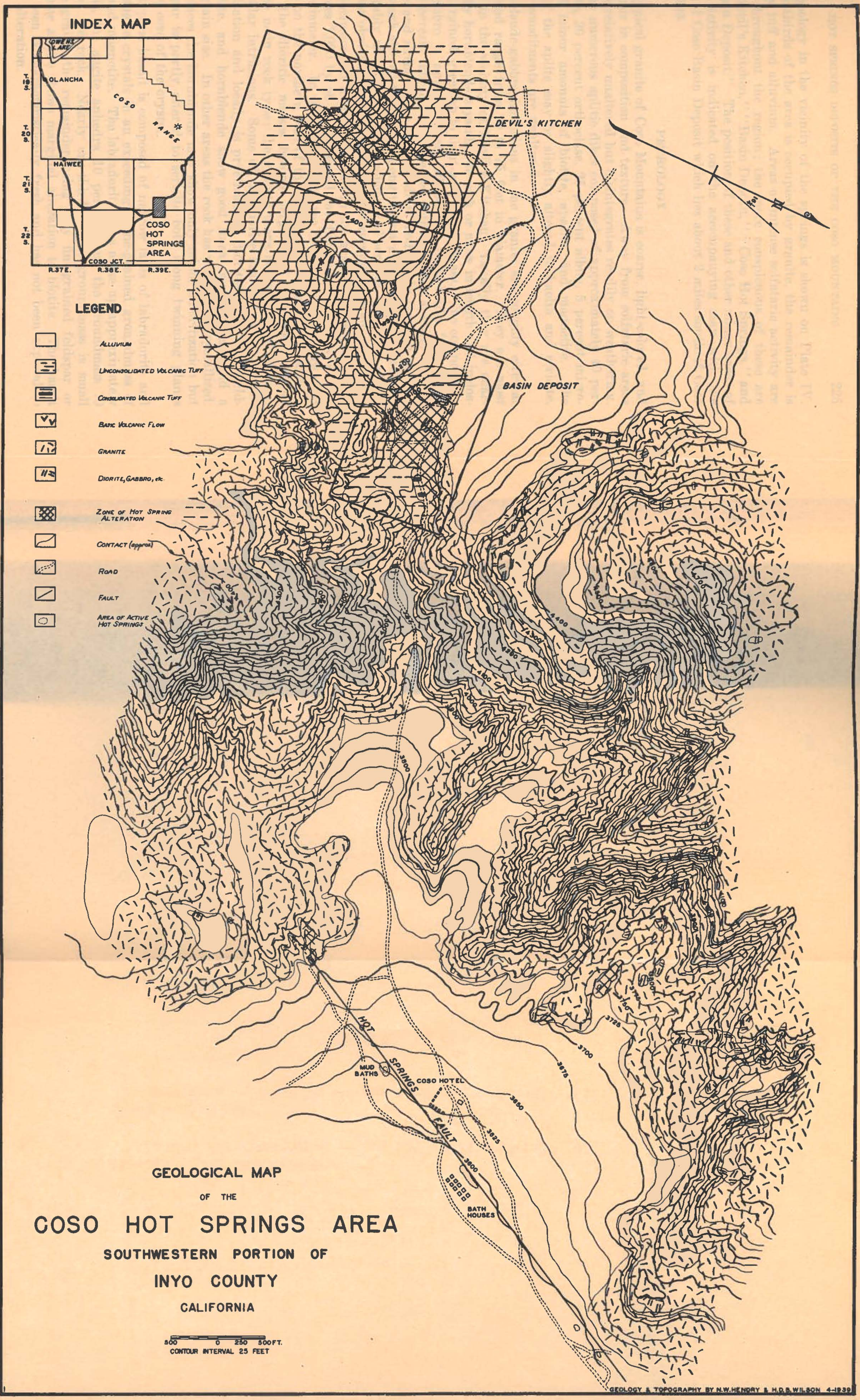
[6] Schultz, J. R., A late Cenozoic vertebrate fauna from the Coso Mountains, Inyo County, California: Carnegie Inst., Washington Pub., no. 487, p. 80, 1937.

[7] *Op. cit.*, p. 98.



GEOLOGICAL MAP
OF THE
COSO HOT SPRINGS AREA
SOUTHWESTERN PORTION OF
INYO COUNTY
CALIFORNIA

The geology in the vicinity of the springs is shown on Plate IV. About two-thirds of the area is occupied by granite, the remainder is covered by tuff and alluvium. Areas of intense solfataric activity are scattered throughout the region; the more conspicuous of these are named ''Devil's Kitchen,'' ''Basin Deposit,'' ''Coso Hot Springs,'' and ''Coso Basin Deposit.'' The position of these and other minor areas of solfataric activity is indicated on the accompanying map with the exception of Coso Basin Deposit which lies about 2 miles south of Coso Hot Springs.

PETROLOGY

The typical granite of Coso Mountains is coarse, light-colored, and homogeneous in composition and texture. Away from solfataric areas the rock is relatively unaltered but disintegrates readily on weathering. It is cut by numerous aplitic dikes composed of approximately 40 percent quartz, 30 percent orthoclase, 25 percent albite, 5 percent microcline, and minor amounts of biotite, apatite, and magnetite. The feldspar of the aplite may be slightly altered to kaolin and sericite. The other constituents are unaltered.

Hornblende-gabbro inclusions in the granite are roughly circular in shape and range from 20 to 75 feet in diameter. They are most numerous in the vicinity of Devil's Kitchen. Locally they are characterized by hornblende crystals one inch or more in length and inclosing a fine-grained, greenish to light-gray groundmass. The composition of this gabbro is approximately 42 percent hornblende, 28 percent augite, 25 percent labradorite, together with accessory apatite, titanite, magnetite, and zircon. The hornblende is moderately fresh in appearance, although altered to chlorite along the margins, but the labradorite is considerably altered to epidote, zoisite, and sericite. In many places the rock has obviously undergone extensive recrystallization.

The inclusions of diorite material in the granite range from elongated slivers 1,000 by 50 feet to small roughly circular masses 50 feet or less in diameter. In the hot springs area diorite inclusions are most numerous on the northern side of the Coso road. North and south of this area the dioritic masses become larger and in some localities become the main rock type; the granite there being present as small and irregular intrusions. Some of the diorite has undergone intense recrystallization and locally is practically a diorite-schist. The feldspar, biotite, and hornblende show good lineal arrangement and a uniform grain size. In other areas the rock has not been recrystallized. In such places the hornblende may show only minor chloritization but the feldspar is partly altered to sericite both along twinning planes and at the core of the crystal.

The typical basalt is composed of narrow laths of labradorite and rounded augite crystals in an exceedingly fine-grained groundmass of feldspar and magnetite. The labradorite laths make up approximately 20 percent, the augite anhedra 10 percent, and the groundmass 70 percent of the rock. Nearly one-third of the groundmass is small magnetite grains, the remainder being very fine-grained feldspar or glass. Some augite shows marginal alteration to biotite. The basalt wherever seen is characteristically fresh and has not been exposed to solfataric alteration.

The rhyolitic flows, obsidian, tuff, and volcanic breccia which occur throughout the Coso hot springs area apparently are derived from a nearly north-south line of craters located half a mile west of Devil's Kitchen. Some of these cones are more than 700 feet high, nearly circular, and composed of glassy lava fragments showing good flow structure. The large quantity of volcanic ash and breccia which blankets the surrounding country attests to the explosive character of the eruption.

A deeply excavated canyon at the Devil's Kitchen shows granite overlain by at least 100 feet of interbedded acidic lava flows and indurated ash beds. Well-indurated beds of volcanic breccia outcrop at intervals along the highway east of the Kitchen. The only exposed contact of breccia and underlying granite may be seen about 2,000 feet east of the Basin deposit and south of the main highway. The breccia lies on an uneven weathered granite surface which in places slopes as high as 35 degrees. Sand and granitic pebbles predominate in the lower beds and are overlain by tuff. The series of thin beds has a total thickness of approximately 12 feet.

Lava from the rhyolitic cones is largely composed of glass and a few small grains of quartz and fine biotite plates, together with small needle-like crystals aligned with the flow texture of the glass. Although these crystals cannot be positively identified many of them are probably quartz or feldspar. The light-brown, porous, rhyolitic flow breccia is composed wholly of volcanic glass and shows excellent flow structure. The vesicles are elongated and much of the glass appears as long fibers which bend around the vesicles.

South of Devil's Kitchen somewhat different characteristics are shown by the lava, which is fairly dense, fine-grained, and light gray in color. About 20 percent of the rock is quartz phenocrysts and 5 percent feldspar phenocrysts, both of which have an average diameter of 2 millimeters. Biotite and muscovite are minor accessories. Secondary quartz veins both the matrix and the primary phenocrysts. Spherulites are abundant.

The volcanic breccias and tuff are composed largely of fresh, unaltered volcanic glass. The coarser-grained tuffs contain many sand grains and presumably were water-laid. In addition, the tuff contains fragmental crystalline material of which quartz is most abundant, but orthoclase, sanidine, and andesine are also common. Microcline, hornblende, biotite, muscovite, and sericite are found in minor amounts. Limonite and hematite sometimes occur as coatings on other grains. The feldspar shows a wide range in alteration, some grains are fresh, others are mostly altered to sericite. The matrix of this tuffaceous material is composed almost entirely of glass.

The indurated tuffs are usually cemented with opal which, when present in large amounts, makes the tuff extremely hard and gives it a shiny siliceous appearance. Opal cement may comprise 20 percent of the rock. In a few places the cement is in part calcite and iron oxides presumably derived from the hot springs, or a yellow amorphous material apparently derived from alteration of the volcanic glass.

SOLFATARIC ALTERATION

The Coso hot springs area is unusually favorable for the study of solfataric action because rocks in the solfataric zones have been intensely altered, though away from the zones they are comparatively fresh. In areas of intense alteration the rocks have been reduced to a very porous pulverulent mass composed entirely of opaline silica. In many places it is difficult, if not impossible, to determine the nature of the original host rock. The most resistant rock material is dark volcanic glass present as fragments in the tuff. Its apparent resistance to alteration may in part be due to its extremely low porosity.

The alteration produced by the hot liquids and gases of the solfataric vents can be classified as silicification, kaolinization, and sericitization. The first indication of alteration as the solfataric zone is approached is shown by the addition of silica, usually in the form of opal but sometimes as chalcedony. This may be accompanied by sericite, usually restricted to feldspar or feldspar fragments. The opal or chalcedony appears as an irregular deposit in the matrix of the tuff, as a matrix replacement around fragments of volcanic glass, as small veinlets cutting tuff or granite, or as indefinite aggregated areas in granitic rocks. Kaolinization is particularly noticeable in rocks containing substantial amounts of volcanic ash. The kaolin forms as a coating on the glass and tuff fragments and sometimes apparently protects them from the complete opalization found in adjacent granitic material.

The granitic rocks show an interesting gradation in alteration in the vicinity of solfataric vents. The typical unaltered granite contains about 10 percent andesine, 15 percent albite, 30 percent antiperthite, 15 percent microcline, 25 percent quartz, 10 percent biotite, and minor amounts of magnetite and apatite. The andesine may be partially altered to sericite and kaolin but the other feldspathic constituents are fresh. Biotite may show some bleaching accompanied by the segregation of iron oxides parallel to cleavage directions. The first effect of solfataric alteration is shown by a bleaching of feldspar and biotite accompanied by deposition of opaline silica. Under more intense alteration the granite decreases markedly in specific gravity, the porosity increases, much of the feldspar is apparently removed, biotite is strongly bleached, and only quartz remains relatively unaltered. This stage of alteration is well shown by much of the granite exposed in the tunnels of the Basin Deposit and the road cuts at the southwest end of this deposit. Here the granite consists of a light buff, poorly consolidated mass which still preserves a granitic texture although the rock is largely composed of clay. Under the microscope this rock appears to consist of 25 percent quartz, 10 percent bleached biotite, 10 percent calcite, 5 percent magnetite, 2 percent andesine, 48 percent clay, and minor amounts of chalcedony.

Closer to the vents the granite is dirty white in color, and is composed of clay in which no dark constituents are visible, though a few quartz grains can be recognized. Under the microscope this rock is seen to contain about 30 percent quartz, the remainder of the material being clay through which magnetite is scattered as fine aggregates or individual grains.

In some areas the granite has undergone still more extreme alteration. In such places it is chalky in appearance, white to buff in color, and is composed almost entirely of fine-grained porous opal. Small particles of original quartz may still be recognized under the microscope but all of the other original minerals have been completely replaced by opal. This intensive opalization is often localized in the vicinity of small steeply dipping faults and the opalized material may grade within a few inches to kaolinitic alteration. However, even under the most intense alteration the granite preserves suffiicent of its coarse texture to distinguish it from altered volcanic material.

The rhyolitic lavas and tuffs, like the granite, are comparatively unaltered in areas removed from solfataric action. They have a characteristic buff color and show virtually no devitrification of the volcanic glass. Approaching the solfataric zone these rocks show increasing opalization and bleaching together with gradual devitrification accompanied by development of clay minerals. The tuffs and lavas, unlike the granite, never show complete opalization. Even under the most intensive alteration they preserve their banded appearance and fragments of unaltered volcanic glass, and areas of clay containing a core of volcanic glass.

SOLFATARIC AREAS

Three major loci of solfataric action are present within the described area. These are the Devil's Kitchen, the Basin Deposit, and Coso Hot Springs. The Devil's Kitchen is located on the line between Secs. 7 and 8, T. 22 S., R. 39 E., M. D. The Basin Deposit occurs about 2,000 feet northeast of the Kitchen, in the N½ Sec. 8. The Coso Hot Springs are about 2 miles to the northeast in the east central part of Sec. 4. Flowing hot springs occur in the Devil's Kitchen and in Coso Hot Springs.

At the Devil's Kitchen and the Basin Deposit, introduced minerals include opal, chalcedony, cinnabar, metacinnabar, sulphur, hematite, koalinite, and various iron sulphates. Cinnabar and metacinnabar occur both as painty disseminations throughout the opalized granite and tuff, and as narrow veinlets, subparallel to the bedding of the tuffs. At no place has mining development exposed any extensive concentration of mercury sulphides. In many places the cinnabar is accompanied by hematite. Sulphur is most abundant in the Devil's Kitchen where it forms as small but very well-developed crystals around the margin of small vents, on the sides of fragments, in breccia, and as black amorphous surface coatings on the altered rocks. Its deposition is obviously going on at the present time. In the upper levels at the south end of the Kitchen an attempt was made to mine sulphur. Alum and iron sulphate occur throughout the altered rocks. Alum commonly occurs as delicate white fibers that have a distinctly astringent taste. The iron sulphate is present mainly as an amorphous or very fine-grained green coating or crust on opalized wallrock.

No cinnabar or metacinnabar is present at Coso Hot Springs, but hematite, clay, opal, alum and iron sulphate are found in variable amounts.

STRUCTURE OF SOLFATARIC AREAS

While the Kitchen, Basin Deposit, and Coso Hot Springs zones occur along a fairly definite northeast line there is no evidence at the first two localities of any northeast-trending structures that might control the localization of these zones. At the Kitchen the greatest extent of the altered area is north and south but there is nothing to indicate that it is anything but an irregular alteration zone around a central vent.

The Basin Deposit has its greatest extent roughly parallel to the major east-west trend of the small valley in which it occurs. Although small faults and breaks are to be found at several places, they do not indicate any major structure indentifiable from the surface. The distribution of the mining pits appears to be haphazard.

The Coso hot springs, by contrast, are very clearly arranged along the east side of a small fault scarp which trends N. 30° E. and dips presumably to the east. This fault parallels the trend of Coso Valley at this point and probably is subsidiary to a major fault system. In the vicinity of the hot springs the fault shows a well-defined scarp that has an average elevation of about 10 feet. This fault can be traced for at least a mile and a half to the northeast. A short distance south of the main mud pit it appears to horsetail in the granite.

THE HOT SPRINGS

A number of active hot springs are located along the east side of the fault. These springs maintain a small pond at the surface and are piped to the Coso Hotel for heat and water. The surface appearance of the springs differs markedly from place to place—some are clear and transparent, others are loaded with white silt, and others are brick red from suspended iron oxides. The color change from white to red may be observed in vents only 3 or 4 feet apart.

The water level between springs 20 feet or less apart may differ by as much as 2 feet. This strongly suggests that the springs maintain individual channelways to a substantial depth. However, all of the springs show a marked seasonal variation in flow. This can be most readily observed in the large bath pit several hundred feet south of Coso Hotel. This pit is about 150 by 100 feet in area and 15 feet deep. The springs in the bottom of this pit continually discharge steam and hot sulphate waters. During the late summer the flow from these springs is only enough to maintain a very shallow, small pool in the bottom of the pit, whereas during the winter season the pool may be maintained at a maximum depth of 5 or 6 feet over the entire pit area. Evidently there is considerable intermixing of ground water and meteoric waters in these springs.

At the pit mentioned above, and also at other springs along the fault, the surrounding granitic rock has been altered to an extremely fine-grained white clay. This clay, which has long been used as a mud bath, is composed almost entirely of opaline silica and one of the kaolin-type minerals, probably nacrite or dickite, and contains in addition less than 0.25 percent of extremely fine-grained quartz grains. An analysis of this mud, collected by Mr. M. Dailey, is given in Table 1.

TABLE I

COSO BATH MUD

Constituent	*Composition (percent)*
SiO_2	50.50
Fe_2O_3	1.44
Al_2O_3	20.16
TiO_2	0.80
CaO	0.68
MgO	0.20
K_2O	1.45
Na_2O	0.45
H_2O minus 105° C	3.63
H_2O plus 105° C.	18.63
B_2O_3	None
P_2O_5	Trace
SO_3	1.39
Cl	0.13
CO_2	0.42
	99.88

Analyst, Smith-Emery Company, Los Angeles.

TABLE II

ANALYSES OF WATER FROM COSO HOT SPRINGS, INYO COUNTY, CALIFORNIA

(Constituents are in parts per million)

	Sample 1	*Sample 2*
Properties of reaction:		
Primary salinity	5	13
Secondary salinity	5	18
Tertiary salinity	90	69
Primary alkalinity	0	0
Secondary alkalinity	0	0
Tertiary alkalinity	(?)	45

Constituents	*By Weight*	*Reacting Values*	*By Weight*	*Reacting Values*
Sodium (Na)	49	2.13	81	3.52
Potassium (K)	11	.29	12	.31
Lithium (Li)	Trace	Trace	----	----
Ammonium (NH_4)	Trace	Trace	----	----
Calcium (Ca)	45	2.25	59	2.84
Magnesium (Mg)	2.4	.20	34	2.80
Iron (Fe)	122	4.98	83	2.97
Aluminum (Al)	201	22.22	56	6.20
Hydrogen (H)	16	15.98	12	11.67
Sulphate (SO_4)	2,308	48.05	1,400	29.18
Nitrate (NO_3)	Trace	Trace	0	.00
Chloride (Cl)	Trace	Trace	40	1.13
Carbonate (CO_3)	0	.00	0	.00
Metaborate (BO_2)	----	----	0	.00
Phosphate (PO_4)	Trace	Trace	Trace	Trace
Silica (SiO_2)	----	----	411	13.59
	2,754.4	----	2,188	----

1. Main Spring. Analyst, Oscar Loew (1876). Authority, Wheeler report.
2. Main Spring. Analyst and Authority, F. M. Eaton (1910).

FIG. 1. Coso Hot Springs quicksilver deposit, Inyo County. *Photo. by Walter W. Bradley, October 1941.*

FIG. 2. Mud bathing pool, Coso Hot Springs, Inyo County. *Photo. by Walter W. Bradley, October 1941.*

Fig. 3. Devil's Kitchen from the west side. The light-colored patches are zones of alteration. The Coso quicksilver mill can be seen on the left.

Fig. 4. A portion of the Basin deposit, and the Coso quicksilver mill. A large volcanic cone can be seen in the background.

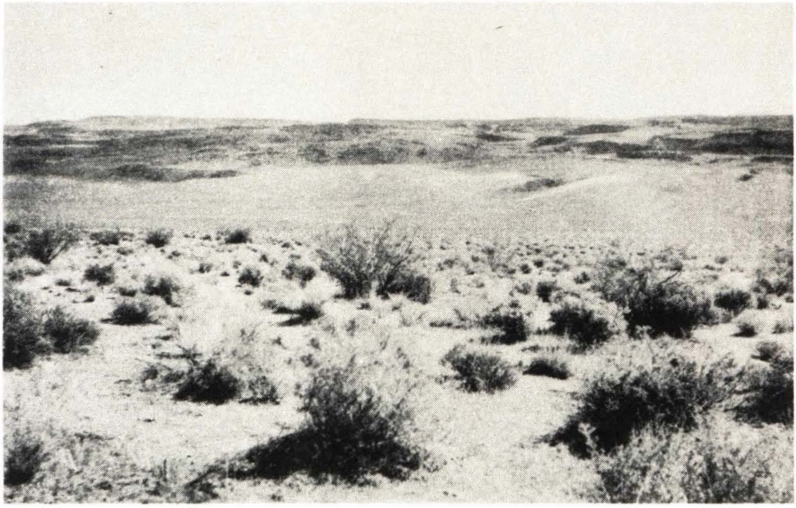


FIG. 5. View to the east from Coso Basin. The mountains in the background are cut by a series of step faults. Basic lava covers a large portion of these mountains.

FIG. 6. Basin deposit, pits and trenches. The headframe of the 30-foot shaft can be seen to the right. The light-colored material is highly altered volcanic tuff.

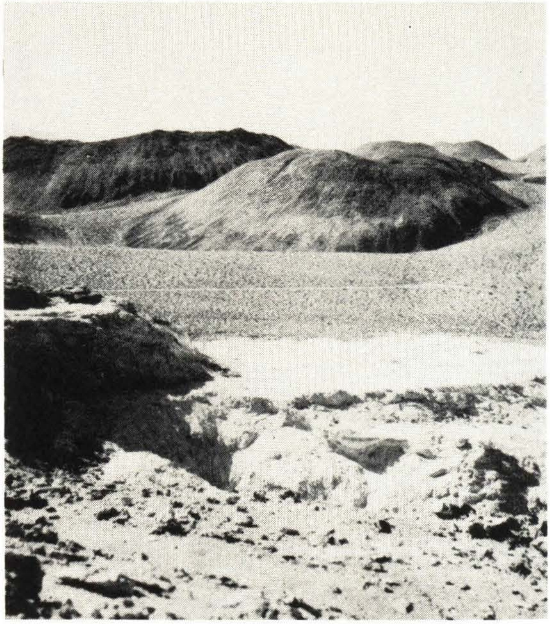


FIG. 7. View from the top of Devil's Kitchen to the northwest. In the foreground are pits in the altered tuff. Several volcanic cones can be seen in the background.

FIG. 8. Coso fault. The scarp can be seen in the alluvium. The fenced area is a zone of active springs.

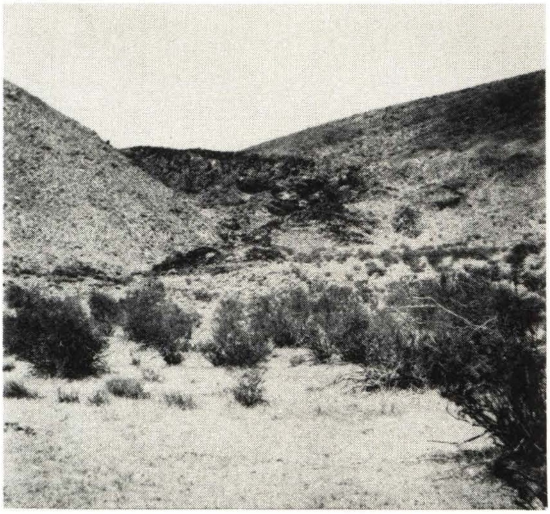


FIG. 9. A basic lava flow to the southeast of the map area, just west of the Coso Basin. The lava has flowed down a narrow canyon in the granite.

FIG. 10. A large cut on the west side of Devil's Kitchen. The bedding of the tuffaceous rocks can be seen in the upper part of the picture. This is a very active part of the Kitchen.

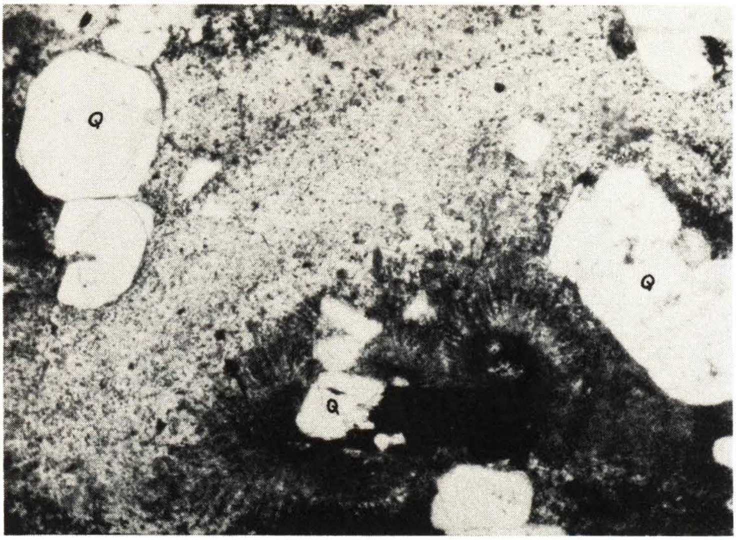


FIG. 11. Rhyolitic lava south of Devil's Kitchen showing phenocrysts of quartz and spherulites in the fine-grained groundmass of quartz and feldspar. Quartz (Q). x30.

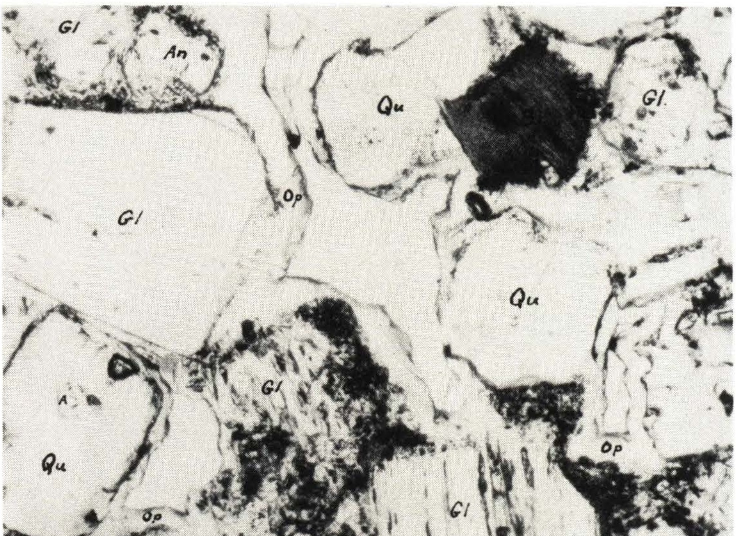


FIG. 12. Cemented volcanic breccia. Opal deposited in open spaces between fragments of glass, quartz, and biotite. Opal (Op), quartz (Qu), biotite (Bi), andesine (An). x110.

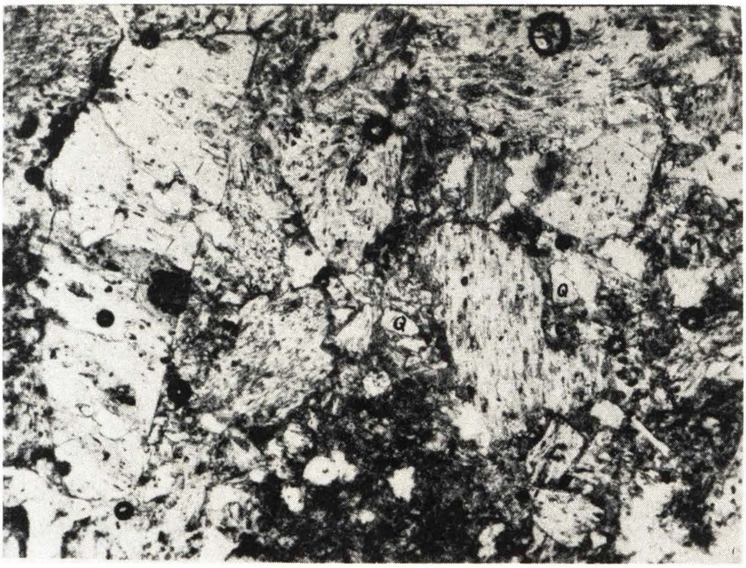


FIG. 13. Slightly altered volcanic breccia from Devil's Kitchen. Two small fragments of quartz (Qu). Large fragments are glass, matrix is largely glassy but contains a small amount of clay (C). x110.

FIG. 14. Cemented volcanic tuff. Two glass fragments (Gl) cemented by opal (Op) and palagonite (Pa), the darker cementing material. x110.

FIG. 15. A portion of the hornblende gabbro intrusive rock type. Augite (Aug) is partially altered to hornblende (Hblende) in this picture. Small inclusions of partially altered augite are present in the main hornblende crystal. x30.

FIG. 16. A portion of an original granite which has undergone "moderate" alteration as a result of the action of hot gases and solutions. The andesine (And) is partially altered to clay (dickite or nacrite) and the quartz (Qtz) shows signs of corrosion. x110.

Although there are a number of fumarolic vents discharging gases in the Devil's Kitchen and Basin Deposit areas, active springs are limited to two, both in the Kitchen zone. One of these springs contains a substantial amount of suspended clay which gives it a milky color, the other is a clear white spring which appears to be depositing very little material.

CHEMICAL COMPOSITION OF THE SPRINGS

Three chemical analyses of water from the hot springs are available in the literature. Two analyses from the springs in the bath pit as quoted by Waring[8] are given in Table 2. Another analysis of water taken from the springs supplying the hotel is given in Table 3. These analyses all show the waters to contain a very high sulphate content together with substantial amounts of iron, aluminum, silica, calcium, and magnesium. There is a marked difference in the analyses made during a period of more than 50 years. It is not possible to determine the extent to which differences between the three analyses represent a change in the composition of the water rather than a change in the accuracy of the chemical determinations. However, some of the changes are so large as to suggest a substantial variation with time in the chemical composition of the spring waters.

TABLE III

COSO MINERAL WATER

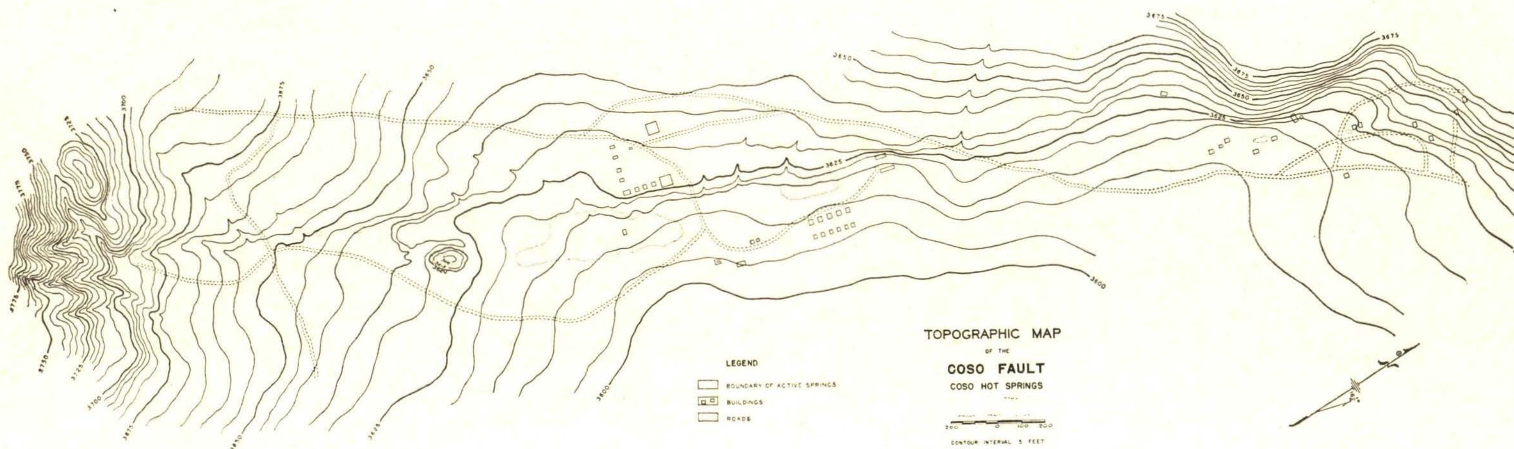
Constituent		*Composition (parts per million)*
SiO_2		458.0
Al_2O_3		570.4
Fe_2O_3		13.6
P_2O_5		0.7
B_2O_3		0.0
$CaSO_4$		227.6
$MgSO_4$		5153.0
K_2SO_4		95.8
Na_2SO_4		1840.0
NaCl		3.8
	Total solids	8362.9
H_2SO_4		452.2
$KMnO_4$		5.5

Analyst—E. F. Williams, Arthur R. Maas Laboratories, Los Angeles, California

SPECTROGRAPHIC ANALYSES OF HOT SPRINGS

In order to investigate variations in the minor constituents of water from the different springs, samples were collected from seven localities around Coso Hot Springs and from the main spring at Devil's Kitchen. These water samples were filtered and evaporated to dryness. A qualitative spectroscopic analysis of these eight samples is given in Table 4. Sample No. 1 was taken from Devil's Kitchen, samples No. 2 to 8, inclusive, were taken from the Coso Hot Springs area. The spectroscopic analyses were made in the laboratories of the Department of Geology, California Institute of Technology.

[8] Waring, G. A., Springs of California: U. S. Geol. Survey Water-Supply Paper 338, pp. 149-151, 1915.



TOPOGRAPHIC MAP
OF THE
COSO FAULT
COSO HOT SPRINGS
LEGEND
BOUNDARY OF ACTIVE SPRINGS
BUILDINGS
ROADS
200 0 100 200
CONTOUR INTERVAL 5 FEET
3775
3750
3725
3700
3675
3650
3625
3600

The analyses presented in Table 4 show a remarkable similarity both in the elements present and in the amounts for different samples. This is particularly surprising because these water samples came from red springs, white muddy springs, and clear springs, and also because the samples showed a considerable variation in the total amount of solids.

Another striking feature of these waters is the variety of elements present. To the 23 elements shown in Table 4 there must be added chlorine, sulphur, and carbon, whose presence has been proven chemically but which are not observable in an ordinary spectroscopic analysis. The presence of elements such as manganese, boron, zinc, lead, tin, vanadium, titanium, nickel, chromium, bismuth, and silver is strongly suggestive of a hypogene origin of these waters. One curious feature is the absence of mercury in solfataric water from the Devil's Kitchen, although cinnabar has been deposited throughout the rocks and its presence has been reported in the gases by several observers. Either the fluids are no longer transporting mercury or else it is present in the discharge only part of the time.

TABLE IV

SPECTROSCOPIC ANALYSES OF COSO HOT SPRING WATER

Sample No.	(Quantitative estimates, in per cent)							
	1	2	3	4	5	6	7	8
Element:								
Ca	10	10	10	10	10	10	10	10
Si	1–10	10	10	1–10	1	1–10	1	1–10
Al	10	1–10	1	1	1	1	1–10	1–10
Mg	1–10	1–10	1–10	1	1	1	1	1–10
Fe	1	.1	.1–1	1	.1	.1–1	.1–1	.1–1
Na	.1–1	1	1	.1–1	.1–1	.1–1	.1	.1–1
K	1	.1–1	.1–1	.1–1	.1–1	.1–1	.1–1	.1–1
Mn	.1	.1	.1	.1	.01–1	.01–1	.01	.1
Sr	.1	.1	.1	.1	.1	.1	.01–1	.1
Cu	.01–.1	.01–.1	.01–.1	.01	.01	.01–.1	.01–.1	.01–.1
Zn	.01–.1	.01	.01	.01	.01	.01	.01	.01
Ba	.01	.01	.01–1	.1	.01–1	.01	.001–.01	.01
B	.01–1	.01–.1	.01	.01	.01	.001–.01	.01	.001–.01
Pb	.01	.01	.01	.01	.001–.01	.001–.01	.001–.01	.01
Sn	.01	.01	.001–.01	.001–.01	.001	.001	.01–.001	.01–.001
V	.01	.001	.001	.01–.001	.01–.001	.001	.001	.001
Ti	.01	.001–.01	.001–.01	.001–.01	.001–.01	.001–.01	.001–.01	.001–.01
Ni	.01	.001	.001	.001	.001	.001	.001–.01	.001
Cr	.001–.01	.001	.001–.01	.001	.001–.01	.001–.01	.001–.01	.001–.01
Bi	.001	.001	.001	.001	.001	.001	.001	.001
Ga	.001	---	---	---	---	---	---	---
Be	tr	tr	tr	tr	---	---	tr	tr
Ag	.0001–.001	.0001	.0001–.001	.0001	.0001	.0001	.0001	.0001
Per cent by weight of dissolved salts	0.70	0.23	0.41	0.37	0.36	0.43	0.69	1.00

Sample: Description and location

1. Clear water from main spring in Devil's Kitchen, about 50 feet south of concrete mud bath basin.
2. Clear water from small stream east of shelter at Coso Hot Springs, main springs area.
3. Iron-stained spring, clear water, from spring with concrete pier, south of sample 2.
4. Clear water from spring in stone-cribbed well, 65 feet south and west of shelter.
5. Red water from spring in stone-cribbed well due west of shelter.
6. Deep red water from spring at edge of pond, 45 feet north of sample 5.
7. Milky white water from spring at north end of mud bath pit.
8. Clear water, spring at south end of mud bath pit.

CINNABAR DEPOSITS

The presence of cinnabar in the Coso Hot Springs district was recognized prior to 1925 but no effort was made to exploit the deposits until that year. Since then there have been intermittent attempts at production by several companies. It is estimated that the total quicksilver output from the several deposits in the Coso Hot Springs district totals approximately 200 flasks.

Mercury has been produced mainly from the Devil's Kitchen and Coso Basin deposits although some exploration had been carried on in Coso valley about 2 miles southeast from Coso Hotel. The deposits have been developed by open cuts, pits, trenches and several short adits.

Virtually all the mercury is present in the form of cinnabar, which occurs as small seams, disseminated grains, and ''painted'' coatings throughout the porous, highly altered tuffs and granite. At the Devil's Kitchen the principal minerals accompanying the cinnabar are metacinnabar, sulphur, hematite, alum, and iron sulphate salts. In the Basin Deposit metacinnabar and hematite accompany the cinnabar. Much of the cinnabar rapidly turns black when exposed to sunlight,[9] and metacinnabar is thus less abundant in the deposits than would be apparent from the casual examination of surface material.

Because there are no confining structures, no concentration of cinnabar occurs in the deposits. Cinnabar disseminations are extremely irregular in shape and distribution. Mineralized seams rarely exceed 2 or 3 inches in width. They likewise are irregular both in strike and dip and cannot be traced for more than a few feet in any direction. A number of narrow gouge seams, possibly the result of slumping in the wall rocks as alteration proceeded, apparently have acted as minor controls on cinnabar distribution.

Eighteen samples were analyzed, of which about one-half were picked from supposedly high-grade seams and pockets in the altered tuff and granite. The highest assay was obtained from a small stringer which showed 1.1 percent mercury. Carefully selected areas may show a mercury content, across a foot or so, of as much as 0.5 percent or 10 pounds to the ton. However, the average content of altered rock is very slow, being less than half a pound per ton, and even selective mining will probably not yield an average production of much better than a pound to the ton. The district affords an excellent example of the deposition of cinnabar under very near-surface conditions, where governing structural control is lacking.

[9] Dreyer, R. M., Darkening of cinnabar in sunlight: Am. Mineralogist, vol. 24, no. 7, pp. 457-461, 1939.

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PLATE V

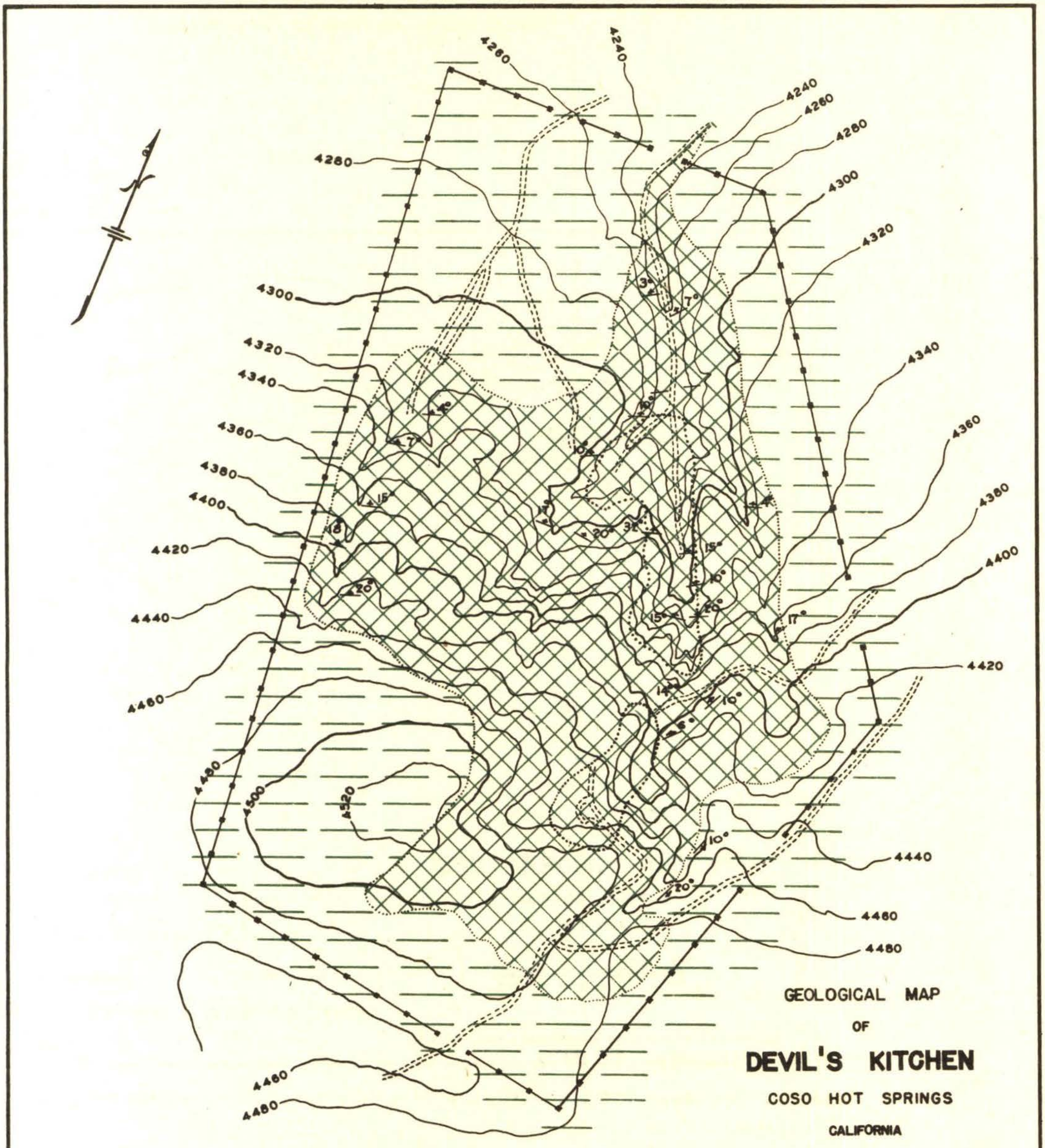

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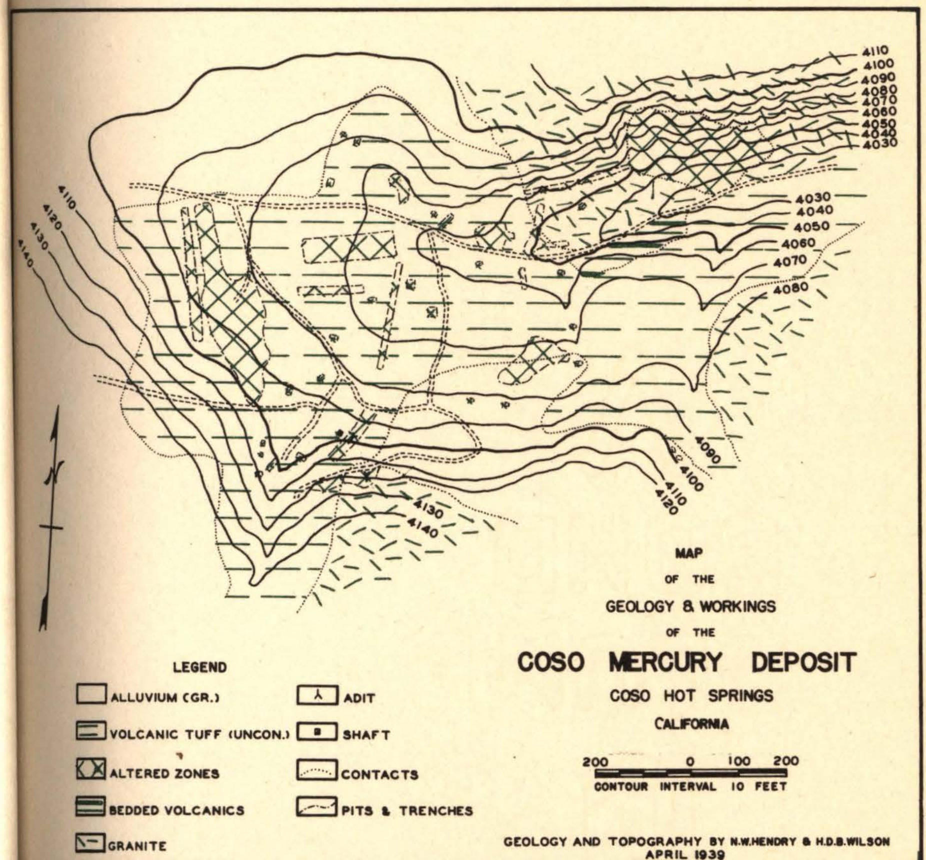
PLATE VI



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